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PROGRESS WITH VIS-5D / DISTRIBUTED VIS-5D

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1. INTRODUCTION

VIS-5D is a system for interactive visualization of large atmospheric data sets such as those generated by numeric weather simulations. It is a simple yet powerful tool used by scientists for both analysis and presentation of their data. VIS-5D is freeware; one can obtain the software at no charge, evaluate it, and use it if it fits one's needs.

VIS-5D was first demonstrated at the AMS annual meeting in January 1989 and described in a paper (Hibbard and Santek 1990). Originally, VIS-5D was only available on Stellar workstations. Since then we have ported the software to SGI and IBM workstations. Coupled with the dramatic drop in prices for 3-D graphic workstations, the number of people using VIS-5D has increased greatly.

Distributed VIS-5D is a variation of VIS-5D designed for visualization in a network environment. With this system, the data do not have to be on the workstation to visualize it. By splitting the program into two parts which run on a supercomputer and graphics workstation, larger data sets can be visualized than practical with a single workstation.

2. OVERVIEW OF VIS-5D

VIS-5D works with multi-variable, time varying data in the form of a five-dimensional grid. Three dimensions correspond to space, one dimension is time, and another data dimension enumerates multiple physical variables. For example, a thunderstorm data set may contain physical variables for potential temperature, pressure, cloud water, and wind speed spanning 50 time steps and a spatial volume of size 30 by 30 by 25 grid points. In this case, the data set would contain 4.5×10^6 data points (4*50*30*30*25). On a workstation with 256 MB of memory, VIS-5D can visualize data sets containing as many as 1.25×10^8 points.

The three space dimensions form a regular-spaced, rectangular domain displayed as a 3-D box on the screen. The physical variables which comprise the data set can be depicted inside the box in the following formats:

- Iso-level contour surfaces with optional transparency.
- Horizontal and vertical contour line slices with selectable contour interval.
- Horizontal and vertical color slices with interactive data-to-color mapping.
- Interactive wind trajectory tracing using a 3-D cursor.
- Horizontal and vertical wind vector slices with adjustable scaling and density.

VIS-5D is completely controlled using a graphical user interface. The mouse is used to rotate, move, and animate the 3-D volume while buttons, sliders, and type-in widgets control program options.

Most data sets visualized with VIS-5D are time varying. The user controls animation and single stepping, either forward and backward in time. A combination analog/digital clock in the 3-D viewing window shows the current time.

To manage the display of the physical variables in the various formats there is a widget button for every possible combination of variable and depiction format. As implemented, the control panel window contains a matrix of buttons in which each physical variable is represented by a row and each depiction format is represented by a column. To display a vertical contour slice of the variable TEMP only requires clicking on the button in the TEMP row and vertical contour slice column. Similarly, if U, V, and W wind components are available, extra buttons will be present for wind vector slices and trajectories.

When the display of any variable is activated, a pop-up window will appear which contains any applicable options. For iso-level contour surfaces, the pop-up window contains a slider to change the iso-level. For wind vector slices, the pop-up window contains type-in widgets to change the vector lengths and density. Only one options window for each type of graphic is displayed at a time to prevent screen clutter.

In addition to graphical widgets, direct manipulation techniques are used in VIS-5D. For example, the default location of a horizontal or vertical slice is through the center of the box. To move the slice to a different location we let the user drag it directly with the mouse. Similarly, when tracing wind trajectory motions an initial location must be selected in the 3-D volume. This is done by dragging a 3-D cursor inside the box using the mouse. We have found that direct manipulation is the best way to handle these interactions because it is simple to use and it eliminates extra slider or dial widgets.

Other features of VIS-5D include:

- User-definable topography and map lines.
- Text annotations with any selected font.
- Antialiasing, transparency, line width, and full-screen rendering options.
- Save and restore of current graphics.
- Graceful handling of missing data.

Because VIS-5D was designed to deal with a singe type of data it works very efficiently. The 5-D grid data is compressed and the internal representation of iso-level contour surfaces, slices, etc. is in a compressed format as well. VIS-5D also utilizes multiple processors to compute the iso-level contour surfaces or slices for each time step in parallel. By using coarse grained parallel programming, near linear speedups can be obtained by increasing the number of processors. For these reasons a number of people have turned to VIS-5D after finding that other visualization systems are too slow or limit data capacity.

3. VIS-5D IN USE

VIS-5D has been used by atmospheric scientists at the University of Wisconsin and other sites for several years now. During that time it has evolved to serve three distinct purposes:

- As a debugging/analysis tool: Those involved in atmospheric modeling use VIS-5D as a diagnostic tool. Typically, after a number of time steps have accumulated, VIS-5D will be used to visually inspect the progress of the model. If there is a problem it can be quickly discovered and diagnosed.

- As a teaching tool: It is not uncommon for a teacher or researcher to bring groups of people into the lab for a VIS-5D session. Concepts which are difficult to explain verbally or display in 2-D can be naturally illustrated with VIS-5D.

- As a presentation tool: It has become common practice for scientists to produce a VIS-5D video to accompany a research paper for presentation at conferences. During only an afternoon's time, some very informative and interesting videos have been made.

Overall, users seem to be very happy with VIS-5D's user interface. It has been our experience that people become proficient with the program after only one or two sessions and minimum instruction. This is very important because the average scientist usually does not have time to spend learning a complicated new software system.

4. DISTRIBUTED VIS-5D

The purpose of Distributed VIS-5D is to allow visualization of very large data sets (1.0×10^{10} data points). This is accomplished by dividing the visualization workload between two computers. Essentially, the VIS-5D program is split into two parts: a client and a server. The client program runs on the user's graphic workstation. It provides the user interface and displays the 3-D graphics. The server runs on the computer where the user's data are stored, typically a supercomputer, and is responsible for converting data into geometric primitives. When the user wants to view an iso-level contour surface, slice, etc., a request is sent from the client to the server. The server receives the request, fetches the appropriate data, computes the iso-level contour surface or slice, and sends the resulting geometric description back to the client where it is displayed.

The requests from the client to the server require little network bandwidth. However, the resulting geometric descriptions sent back may be quite large. Descriptions of iso-level contour surfaces computed from a 50 by 50 by 25 point grid are often 100KB in size. A high speed network is required to sustain interactive rates. In fact this project is in part funded by the Gigabit Network Testbed project and intended to be a test application of the network.

Our testing was done using an SGI 340VGX workstation at the UW Madison and a CRAY-2 supercomputer at the NCSA in Urbana, IL connected by a T-1 (1.5 Mbps) network. We discovered two main problems: network congestion and supercomputer process scheduling. Since we were certainly not the only users of the network it was inevitable that we would be competing for bandwidth with other users. When the network was congested we experienced a dramatic decrease in bandwidth but only moderate increases in latency. We found just the opposite problem while using the CRAY-2; the server process would get alternating short periods of high throughput followed by long periods of low throughput. The combination resulted in the user observing wildly varying performance.

For example, if the user selected an iso-level contour surface for viewing and then turned on the animate option he would see a very uneven frame rate. This is because Distributed VIS-5D only sends requests to the server on an as-needed basis. When animation is selected, a sequence of iso-level contour surface requests are sent to the server. Since the server is a parallel program and iso-level contour surfaces may require different amounts of time to be computed they may be send back to the client out of order. This, compounded with the network and scheduling problems, results in an uneven frame rate. In an attempt to solve the problem, we experimented with various techniques to adaptively control the animation rate depending on request/result turn around time. While we were mostly successful, we found no way to effectively deal with unexpected periods of zero throughput.

What does this mean for the user? During hours of heavy network or supercomputer use, one encounters a cycle of delays and bursts in responsiveness. This can be very distracting because slowness and delays make the user wonder if the system has crashed. The solution is to increase the network speed and to change the process scheduling on the supercomputer to give a more even throughput. We may experiment in both of these areas when our network is upgraded to T3 (45 Mbps) and by porting the server to another supercomputer.

Despite the complications involved in distributed visualization, it can be useful as long as it allows you to do something not possible with a single workstation. In our case Distributed VIS-5D allows visualization of much larger data sets than possible previously.

5. SUMMARY

The developers of VIS-5D have worked closely with its users resulting in an exceptional balance between ease-of-use and features.

Three important themes run throughout VIS-5D:

- Interactivity: VIS-5D gives quick responses to user input. When the user does not have to wait for results, he is more likely to try new ideas and explore data in more detail.
- Ease of use: Having a graphical user interface is not sufficient to qualify a program as easy to use. Our philosophy has been "less is more" when it comes to windows and widgets - we avoid presenting our users with unnecessary and confusing choices.
- Versatility: While VIS-5D has a rich variety of visualization methods, the program itself can be used in several unique ways.

There should be no question about the value of scientific visualization. We are now concerned with how to best apply the technology and make it accessible to the people who need it.

6. OBTAINING VIS-5D

VIS-5D is available via anonymous ftp:

```
% ftp vis5d.ssec.wisc.edu
(or % ftp 144.92.108.66)
login:  anonymous
password:  myname@mylocation
ftp> cd pub/vis5d
ftp> ascii
ftp> get README
ftp> bye
```

See section 2 of the README file for complete installation instructions. Since VIS-5D is freeware there is no warranty of any kind. However, we will try to help with any questions or problems addressed to us.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

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